PRELIMINARY REPORT ON THE McLOUTH GAS AND OIL FIELD, JEFFERSON AND LEAVENWORTH COUNTIES, KANSAS

By

WALLACE LEE

PRELIMINARY REPORT ON THE McLOUTH GAS AND OIL FIELD, JEFFERSON AND LEAVENWORTH COUNTIES, KANSAS[1]

By WALLACE LEE[2]

with surface structure maps by HUNTSMAN HAWORTH[3]

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ILLUSTRATIONS

ERRATUM: In running head at top of odd numbered pages, "McClouth" should read "McLouth."

TABLES

ABSTRACT

On August 15, 1941, the McLouth gas and oil field, 15 miles north of Law-
rence, Kansas, had 23 gas wells with an aggregate initial open flow of 170
million cubic feet of gas per day, six oil wells with a probable total potential
of 250 barrels per day of oil of 24 to 25 degrees gravity Bé. Three dry holes
had been drilled. The surface rocks, which are mainly the Lecompton lime-
stone of late Pennsylvanian age, are partly covered by glacial drift. A normal
sequence of Pennsylvanian rocks rests disconformably on Mississippian lime-
stones.

The structure shown by the surface rocks is a northeast-trending gentle
anticline having a closure of less than 20 feet. The closure of the anticline in-
creases with depth. The pre-Pennsylvanian structure is marked by faulting,
which is not noticeable in the surface structure. There seems to be a definite
and pronounced southward shift in the position of the structural crest with
increasing depth.

There are three known gas- or oil-producing zones. Most of the gas comes
from the McLouth sand at the base of the Pennsylvanian rocks. Three wells
produce oil from this zone. The McLouth sand is variable in permeability and
in some structurally favorable areas is lacking in porosity. The weathered
and porous top of the Mississippian rocks yields gas in some wells. This zone
is saturated with oil in some wells but no oil has yet been produced from it.
The lowest producing zone to date is a porous dolomite zone in the undiffer-
entiated Burlington-Keokuk limestones from 125 to 150 feet below the top of
the Mississippian rocks. This zone yields oil in three wells.

Production of gas from the McLouth sand extends far beyond the area of
closure of the anticline as mapped on the gas sand. It is evident that pro-
duction in this zone is dependent more on the presence of permeable sand
than on local structural conditions, though it is possible that the McLouth
anticline may prove to be only a part of a much larger anticlinal structure.
Production of oil from Mississippian rocks seems to be governed more closely
by anticlinal structure than does production from the McLouth sand.

INTRODUCTION

The McLouth gas and oil field is located in northeastern Kansas about midway between Kansas City and Topeka and about 15 miles due north of Lawrence (fig. 1). The producing area includes parts of Jefferson and Leavenworth counties, and all or parts of secs. 28, 29, 32-34, T. 9 S., R. 20 E., and secs. 3-6, T. 10 S., R. 20 E. The field has been named from the village of McLouth, in Jefferson county, which lies less than a mile southwest of some producing wells. The McLouth field is located well within the borders of the
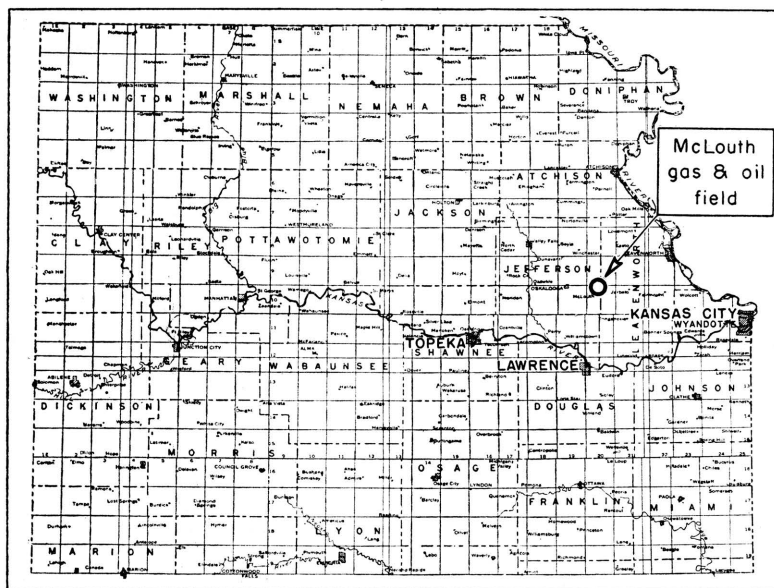
FIGURE 1. Index map of northeastern Kansas showing location of the McLouth gas and oil field.

structural depression called the Forest City basin and is the first field to produce oil from pre-Pennsylvanian rocks in the Forest City basin in Kansas.

This report is a preliminary one, for it is based on information pertaining to development of the field prior to August 15, 1941. The study is sponsored by the State Geological Survey of Kansas and the Federal Geological Survey, as part of a cooperative project to investigate the relationship of oil and gas to stratigraphy and structure in the Forest City basin in Kansas.

The development of the McLouth field began in November, 1939, with the discovery of gas in a well drilled in sec. 4, T. 10 S., R. 20 E. On August 15, 1941, the field contained 23 gas wells, 6 oil wells, and 3 dry holes. The dry holes entered the gas pay sand at points where it lacks porosity and failed to find commercial amounts of oil or gas in deeper rocks penetrated. Little if any water was encountered in any of the wells in the gas sand. The amount of oil produced prior to August 15, 1941, is not large, but study of the field is important inasmuch as its structure presents unusual features that may have bearing on future developments in northeastern Kansas. Widespread interest in the McLouth field on the part of oil and gas operators and of citizens in northeastern Kansas makes desirable the publication of this preliminary report on the area, even though many structural details pertaining to folding and faulting of pre-Pennsylvanian rocks are as yet undetermined.

Discovery of the McLouth field may be credited to Huntsman Haworth, consulting geologist of Wichita and Lawrence, Kansas, whose careful field work on outcrops resulted in the mapping of the anticline on which the field is located. The development of the field up to the present time has been due largely to the activities of D. W. McLaughlin, representing McLaughlin & Sons, principal operator in the field. McLaughlin's persistence in drilling wells in the McLouth area, in spite of the lack of pipe-line facilities and the small production from some of the earlier wells, had resulted on August 15, 1941, in the development of an aggregate total initial open flow of 170 million cubic feet of gas from 23 wells and a potential oil production of approximately 250 barrels per day.

STRATIGRAPHY

The surface of the McLouth field is underlain by alternating beds of limestone and shale of Pennsylvanian age. Inasmuch as ice of the Pleistocene epoch once covered northeastern Kansas, the Pennsylvanian rocks of the area are to a large extent mantled by sand, clay, and gravel deposits of glacial origin.

Pennsylvanian rocks that crop out in the area belong for the most part to the Lecompton limestone of the Shawnee group in the middle part of the Virgil series, of late Pennsylvanian age. The Pennsylvanian rocks penetrated by drilling in the McLouth field are described in Moore's report on the Pennsylvanian rocks of Kansas (Kansas Geol. Survey, Bull. 22, 1937). The nomenclature and stratigraphic classification used in discussing the Pennsyl-

vanian rocks of this area follow the usage of the Kansas Geological Survey and do not necessarily imply its adoption by the Federal Geological Survey. The subsurface Pennsylvanian rocks immediately underlying the Lecompton limestone consist of thin shale and limestone beds of the Shawnee group. The top of the lowest limestone division, the Oread limestone, has been used as a datum for contouring structure (pl. 3 A). Below the Shawnee group is the Douglas group of the Virgil series. In the McLouth field the Douglas group consists mainly of shale and a few thin sandstone beds.

The Douglas group is underlain by the Lansing, Kansas City and Bronson groups of the Missouri series, which consists of alternating beds of limestone and shale. The lowest limestone of the Bronson group is the Hertha limestone, whose base has been used as a datum for contouring the structure (pl. 3 B). That part of the Missouri series below the Hertha limestone consists mainly of shale and is termed the Bourbon formation.

The Des Moines series, which lies below the Missouri series, is mainly shale. Its upper part, the Marmaton group, includes a number of thin limestones not very carefully logged in some wells. The lower thin limestones of the Marmaton group are included in the Ft. Scott limestone. The lower part of the Des Moines series is the Cherokee shale, which consists almost entirely of shale, sandy shale, sand, and some beds of coal. A thin limestone (Ardmore limestone) is present in the upper part of the Cherokee shale. This limestone would be a valuable datum bed except that it is even more frequently omitted from logs than the limestone beds of the Marmaton group. In cases in which the Ardmore limestone can be detected in the samples, its exact depth is sometimes in doubt. Most of the gas and some of the oil of the McLouth field come from a sandstone (here termed the McLouth sand) near the base of the Cherokee shale.

Pennsylvanian rocks are underlain by Mississippian rocks, most of which are limestone. The Mississippian formations that have been identified in the McLouth field are Salem limestone (Spergen of the Federal Geological Survey) and Warsaw limestone of Meramec age; undifferentiated Burlington-Keokuk limestones of Osage age; Gilmore City and Sedalia limestones of Osage or Kinderhook age, Chouteau limestone of Kinderhook age, and Chattanooga shale, doubtfully placed in the Devonian. Some gas

and oil are produced from porous zones in the upper 150 feet of the Mississippian in the McLouth field.

The Chattanooga shale is underlain by Devonian rocks commonly referred to by oil geologists as the "Hunton limestone". Silurian rocks are absent in the McLouth field, as is also the Maquoketa shale. Thus in the McLouth field Devonian limestones rest on the Viola limestone (Kimmswick of Missouri) of Ordovician age. St. Peter sandstone underlies the Viola limestone and overlies the Arbuckle limestone.

STRUCTURE OF FIELD

Huntsman Haworth, assisted by C. B. Taylor, mapped the surface structure of the McLouth field in April, 1939. Structure contours were drawn on the top of the Big Springs limestone member of the Lecompton limestone. Because bed rock in parts of the area is concealed by glacial drift, a number of shallow test holes were dug in order to obtain additional control points for structural mapping. Part of Haworth's original map is presented in fig. 2. This map was revised by incorporating information obtained from deep wells drilled prior to December, 1940 (plate 1). These maps are published with the permission of Mr. Haworth, to whom the writer is also indebted for much detailed subsurface data.

Haworth's map indicates a broad, somewhat irregular, plunging anticline that is about 9 miles long and 2 to 4 miles wide. The axis of the anticline trends northwestward and extends from sec. 1, T. 10 S., R. 20 E., to sec. 7, T. 9 S., R. 20 E. The structure contours in this area, as in other parts of northeastern Kansas, meander somewhat aimlessly, displaying what has been designated by some as "amoebic structure". Several domes with closures of 5 to 20 feet occur on the crest and flanks of the above-described anticline. The McLouth field lies on one of these secondary domes or anticlines on the southwest side of the larger anticline, but the producing area extends far beyond the area of structural closure.

The local structure of the rocks exposed near McLouth, as shown in plate 1, is a broad, gentle anticline about 2½ miles long and one mile wide. The closure, as determined from the surface, is less than 20 feet. A slight structural saddle bisects the crest of the anticline, giving it the appearance of two domes,—a feature that was not suspected in the original work in the area because no outcrops occur in the saddle part of the crest.

DEVELOPMENT OF FIELD

The wells completed prior to August 15, 1941, are shown in plate 1. The three oil wells in sections 4 and 5, T. 10 S., R. 20 E., produce oil from Mississippian limestone, which disconformably underlies the Pennsylvanian rocks of this region. The gas is obtained from a lower Pennsylvanian sandstone. Three wells on the south side of the field yield oil from this sand. The production of each well is shown in table 6 and in plate 3 (C and F).

Drilling of the first well, McLaughlin No. 1 fee, NE NW sec. 4, T. 10 S., R. 20 E., was begun on October 7, 1939, and gas was discovered early in November, 1939, in sandstone near the base of the Cherokee shale of early Pennsylvanian age. This sand is currently referred to by drillers and operators in the field as the "Bartlesville" sand, but is designated in this paper as the *McLouth sand*. Although both the McLouth sand and Bartlesville sand occur in the lower part of the Cherokee shale, they were laid down in sep-
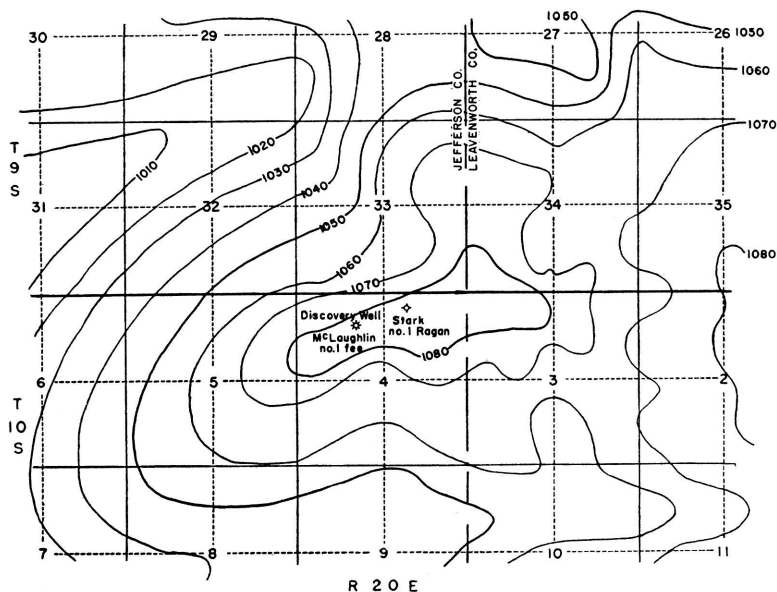
FIGURE 2. Original surface structure map of McLouth field by Hunstman Haworth assisted by C. B. Taylor. Structure interpreted from study of outcrops and shallow pits in April, 1939, before drilling began. Contours drawn on top of Big Springs limestone member of Lecompton limestone. Map shows location of discovery well (McLaughlin No. 1 fee) offsetting a dry hole (Stark No. 1 Ragan). Contour interval, 10 feet. Datum, mean sea level.

arate basins and probably lie at slightly different stratigraphic horizons. In some wells, the McLouth sand is either separated from Mississippian limestone by several feet of dark shale or has shale in its lower part, but in many of the wells sandstone rests directly upon Mississippian rocks.

The discovery well originally gauged 8½ million cubic feet of gas from sand at a depth of 1,426 to 1,440 feet, but the well was later deepened for the purpose of exploring oil production possibilities. From a depth of 1,450 to 1,475 feet an increas in flow of gas into the well was reported. Casing was set and cemented at the top of the Mississippian rocks at a depth of 1,475 feet. Oil and gas were reported as occurring at the top of the Mississippian. Also, porous limestone and dolomite, heavily stained with oil, were penetrated at four other zones between 1,475 and 1,645 feet (170 feet below the top of the Mississippian). Water was reported at depths of 1,635 and 1,650 feet.

The "Hunton" limestone, of Devonian and Silurian age, was penetrated by the discovery well at a depth of 1,872 feet and was drilled to a depth of 1,915 feet. Shows of gas in the "Hunton" limestone were reported. Unsuccessful efforts were made to shut off the water by the use of a packer in order to test this gas zone. Deeper drilling was abandoned after three strings of tools were lost. The hole was then plugged back to the top of the Mississippian rocks. The McLaughlin No. 1 fee well is the deepest thus far drilled in the field; the driller's log is presented in table 1.

Several zones in the discovery well (McLaughlin No. 1 fee), as indicated by the driller's log (table 1), yielded water in minor amounts; some water was found in other wells drilled in the field. Water has been reported most frequently from the zones listed below, but is by no means universally present. No water has yet (August 15, 1941) been encountered in the McLouth sand.

Water-bearing zones that have been found in the McLouth field and the amount of water reported (bailers per hour) are as follows, in downward order: Tonganoxie sandstone member of Stranger formation (2 to 6 bailers); top of Stanton limestone (2 to 4 bailers); top of Wyandotte limestone (2 bailers); top of Hertha limestone (3 bailers to hole full of water); sandstone lenses and beds in the middle and lower Cherokee shale (2 to 20 bailers); porous zones of the Mississippian in structurally low positions, as in Stark No. 1 Ragan well (8 bailers).

TABLE 1. *Driller's log of McLaughlin No. 1 fee well, SW NE NW sec. 4, T. 10 S., R. 20 E., Jefferson County, Kansas.*

Altitude above sea-level at mouth of well, 1,103 feet. Drilling began October 7, 1939; completed December 14, 1939.

	Thickness, feet	Total depth, feet		Thickness, feet	Total Depth, feet
Soil	3	3	Shale	5	765
Clay	4	7	Lime	5	770
Shale	23	30	Shale	17	787
Lime	5	35	Lime	5	792
Shale	69	104	Shale	60	852
Lime	12	116	Sand	20	872
Shale	64	180	Red rock	3	875
Red rock	2	182	Shale	30	905
(2 bailers of water per			Lime	45	950
hour at 300 feet)			Shale and lime	20	970
Shale	223	405	Shale	20	990
Lime	45	450	Lime	5	995
Shale	4	454	Sandy shale	24	1019
Lime	5	459	Shale	68	1087
Shale	16	475	Lime	4	1091
Lime	30	505	Sandy lime	4	1095
Shale	20	525	Shale	5	1100
Lime	15	540	Sand	4	1104
(2 bailers of water per			Sandy shale	16	1120
hour at 540 feet)			Shale	67	1187
Shale	23	563	(Correction: 1350		
Lime	15	578	equals 1337		
Shale	20	598			
Lime	8	606	Sandy shale	239	1426
Shale	9	615			
Lime	42	657	Sand - gas	17	1443
Shale	4	661	Shale	4	1447
Lime	7	668	Sdy. shale	3	1450
Shale	4	672	Sand - gas	25	1475
Lime	40	712			
Shale	2	714	Mississippi lime	345	1820
Lime	5	719	show oil, gas		
Shale	2	721	Shale	55	1875
Lime	25	746			
Shale	4	750	Lime (Devonian		
Lime	10	760	"Hunton") gas	40	1915

("Bartlesville" (McLouth of this report) — bracketed label for Sand - gas, Shale, Sdy. shale, Sand - gas rows)

The second well drilled in the McLouth field (Young and Longwell No. 1 McLeod), which was started April 7, 1940, is located a short distance south of the surface crest of the anticline in center of S½ NW SW sec. 4, T. 10 S., R. 20 E. This well penetrated as sequence of Pennsylvanian rocks similar to that in the discovery well except that no porous sand corresponding to the McLouth sand of the discovery well was encountered. The position of the McLouth sand is occupied by shale with thin streaks of dense sandstone partly stained by oil but containing no gas. The well was drilled

TABLE 2. *Stratigraphic horizons and divisions in the McLaughlin No. 1 fee well; determinations based on study of samples and residues by Wallace Lee. Correction of depth distributed*

feet

Pleistocene
  Glacial till 0- 30

Pennsylvanian
  Lecompton limestone (base only) 30- 35
  Oread limestone (top)   95
  Tonganoxie sandstone (top) ....   300±
  Stanton limestone (top) (top of Lansing group)   411
  Plattsburg limestone (top)   470
  Wyandotte limestone (top)   520
  Iola limestone (top)   592
  Drum limestone (top)   609
  Block limestone (top)   655
  Winterset limestone (top)   666
  Bethany Falls limestone (top)   712
  Hertha limestone (at base of Bronson group) 743- 763
  Marmaton group 905- 995
  Cherokee shale   995-1475
    Ardmore limestone (top)   1077
    Siltstone above McLouth sand (top)   1415
    McLouth sand ("Bartlesville")   1526-1475

Mississippian (top)   1475
  Salem (Spergen) dolomite   1475-1503
  Warsaw limestone   1503-1530
  Burlington-Keokuk limestone, undivided   1530-1685
  Gilmore City limestone   1685-1708
  Sedalia limestone   1708-1722
  Chouteau limestone   1722-1820

Devonian (?)
  Chattanooga shale   1820-1874

Devonian
  "Hunton" limestone   1874-1915

deeper to test the oil-stained porous zones of the upper Mississippian rocks encountered in the original well. The top of the Mississippian rocks, at a depth of 1,469 feet, showed some free oil, and many samples of Mississippian limestone and dolomite down to a depth of 1,594 feet were found to be porous and stained by oil. When drilled to a depth of 1,594½ to 1,596 feet, the well filled to a height of 1,200 feet with black oil of 20.7 degrees Bé. gravity; 72 barrels of oil were pumped during the first 24 hours and 32 barrels of oil during the next 30 hours.

A considerable amount of caving occurred in the Young and Longwell No. 1 McLeod well during the drilling of the upper part of the Mississippian limestones. This was attributed by some observers to caving in the weathered zone at the top of the Mississip-

pian, but the presence of slickensided chert and comparison of the Mississippian rocks of this and other deep wells of the field indicate that the McLeod well was drilled through a fault or fault zone, as shown in the cross-section of plate 2B. The fault is probably a tension fault having a down-throw of about 60 feet on the south side. The fault strike evidently trends slightly north of east.

Table 6 gives the initial production and other information pertaining to the McLaughlin and McLeod wells and to other wells drilled to the McLouth sand prior to August 15, 1941.

PRODUCING ZONES

Three zones in the McLouth field yield oil or gas,— (1) the McLouth sand, (2) the weathered zone at the top of the Mississippian rocks, and (3) a zone of porous dolomite in the undifferentiated Burlington-Keokuk limestone occurring 121 to 128 feet below the top of the Warsaw formation. In addition to the zones just indicated, shows of gas were reported from the top of the Devonian ("Hunton") in the discovery well. Three deeper zones that have yielded oil and gas in other parts of Kansas have not yet been tested in the McLouth field. These occur in rocks that are designated by oil geologists as Viola limestone, St. Peter sandstone, and Arbuckle limestone.

MC LOUTH SAND

The McLouth sand is the principal gas-producing zone in the McLouth field. Three wells were producing oil from this zone on August 15, 1941. These wells are on the south flank of the anticline and on the downthrow side of the fault. On the north flank of the anticline, a considerable amount of free oil was found in the McLouth sand in Archie No. 1 Shrader well (sec. 28, T. 9 S., R. 20 E.), but the flow of oil was not maintained and the well was finally completed as a small gas well.

The McLouth sand constitutes a zone of sandstone and shale of varying character and occupies the basal part of the Cherokee shale of early Pennsylvanian age. In most wells the zone is 40 to 50 feet thick, but in the depressed belt south of the fault (pl. 3, C and F) the zone is thicker. The sand zone is 89 feet thick in the Magnolia No. 1 Kell estate well and 75 feet thick in Sherrod et al. No. 1 Momyer, but it thins to 33 feet in Apperson and Pundt No. 1

McLeod and to 29 feet in Stark No. 1 Ragan. In some wells the Mc-
Louth sand consists entirely of sandstone, but some parts of the
sandstone lack permeability because of low porosity. In most of
the wells a shale bed in the middle part of the zone divides the
sandstone into upper and lower parts, either or both of which may
be productive depending on the porosity. In a few wells, the Mc-
Louth sand consists mainly of shale with only thin streaks of dense
nonporous sandstone. Six wells (August 15, 1941) have failed to
show appreciable porosity in the McLouth sand: Young and Long-
well Nos. 1, 2, and 3 McLeod; Stark No. 1 Ragan, Sherrod et al. No.
1 Momyer; and Magnolia No. 1 Kell estate. The first three, how-
ever, yielded oil from Mississippian rocks and are not classified as
dry holes. Part of the McLouth sand in the last well was heavily
saturated with oil.

The cross section A-A' (pl. 2) shows the variations in thickness
and lithology of the McLouth sand in a northeast direction across
the field; it was compiled from the study of well logs and from ex-
amination of well cuttings. Only lower Pennsylvanian rocks and
upper Mississippian rocks are shown in the cross-section. Correla-
tion of the columnar sections of the wells utilizes as a datum plane
the top of a distinctive grayish-white siltstone or "white shale"
that is commonly present above the McLouth sand. This siltstone,
2 to 5 feet thick, is a good horizon marker. Its top varies in position
from 11 to 21 feet above the top of the McLouth sand, but in many
of the wells the exact measurement of this interval is difficult to
determine. Some drillers have logged the McLouth sand only if
the rock contained gas or oil.

Much of the McLouth sand is a nonporous sandstone. The low
porosity is either due to the presence of a clay or silt matrix be-
tween the sand grains or to the presence of secondary calcareous
or siliceous cement. Accordingly, the top of the gas sand, as re-

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PLATE 1. Surface structure map of McLouth field by Huntsman Haworth,
with recorded data derived from wells drilled prior to December, 1940. Con-
tours drawn on top of Big Springs limestone member of Lecompton limestone,
altitude of this datum recorded at wells shown with designation "B.S. ls."

The map also shows location of wells completed prior to August 15, 1941 and
position of cross-sections, A-A' and B-B'.

Oil wells in sections 4 and 5 produce from Mississippian dolomite (Burling-
ton-Keokuk); those in section 3 produce from McLouth sand.

Names of owners are given on upper part of lease areas (new land owner
indicated in parentheses) and names of operators in lower part.

Contour interval, 10 feet. Datum, mean sea level.

McLeod—
Wisdom
1 ✳

Anderson

-30- 29 28 27 26-

Shrader
✳

Archie et al

JEFFERSON CO.
LEAVENWORTH CO.

Well Symbols
Dry hole ✧
Gas well ✳
Oil well •
Drilling well ○

Shrader
1 ○

Jackson

1010

1020

T.
9
S.

-31- 32 1030 Brose Bartlett Bartlett 33 34 35-

Woodhead
1 ✳ 1040 1 ✳ 3 ○ 1 ✳

Anderson Archie

1050 Davison
Harris
1 ✳ 1 ✳ 1 ✳ 2 ✳ 2 ○ Edmonds
1 ✳

1060
Magnolia Magnolia McLaughlin Longwell A & B

Sherman
Bower McL.Sons McLaughlin Sons B' Ragan Ragan Steenstry
1 ✳ 1 ✳ & Co. 1 ✳ 1 ✳ A'
1075 B.S. ls. 2 ✳ 1074 B.S. ls. 1087 B.S. ls.

Richard A & B Stark McLaughlin Longwell
Stark
Bower Dark 1 ✳ 1 ✳ Ragan Steenstry Steenstry
1 ✳ (Bower) Dark 1086 B.S. ls. A & B 1 ✳ 2 ✳
1079 B.S. ls. (fee) 1080
McL. McLaughlin Longwell Apperson
1 • and Pundt

T.
10 -6- Sherrod 5 McLeod McLeod 4 Momyer 3 Bankers Life 2-
McLaughlin (McLeod)
McLeod 2 • 2 • 1 •
A 3 • 1085 B.S. ls. Kell Est.
1074 B.S. ls. 1 Young and 1079 B.S. ls. 1070 Sherrod 1 ✧ 1 ✧ 2 •
S. Longwell Young and L. A & B Magnolia Longwell

McLeod
B ✳
1060
Apperson
and Pundt

-7- 8 9 10 11-

R. 20 E.

ported in the well logs, does not represent the same stratigraphic horizon in every well. For structural purposes the position of the top of the McLouth sand has been taken to be coincident with the upper limit of definite sandstone, porous or otherwise, below the siltstone. The siltstone would be an excellent key horizon were it not that in some wells the top of the siltstone lies at an undeterminable altitude, somewhere within a space of 10 feet or more that is represented by a single sample of well cuttings. The thickness of beds between the siltstone and the top of the McLouth sand in the McLaughlin No. 1 fee well, shown in the cross-section, is less than it is in the other wells (pl. 2A). The actual decrease in this interval is, however, only 5 feet; part of this may be due to inaccuracies in estimating the depth of the samples or in interpreting the position of the siltstone or top of the sand in this well.

As shown in the cross-section (pl. 2A), the McLouth sand is variable both as to lithologic character and as to porosity; this variation is due to lateral variations in sedimentation. Some coarse sandstone phases are lacking in porosity, and the clean, coarse permeable sandstone of some wells evidently grades progressively into muddy sandstone and into siltstone, laminated siltstone, and micaceous shale in other wells. In those wells in which the McLouth sand consists of an unbroken vertical sequence of sandstone, the middle part consists of fine sandstone or siltstone that seems to be the local equivalent of the shale and the sandy shale separating the upper and lower sand bodies of other wells. One may regard the sandstone layers as stratified lenses deposited in shallow erosional basins or channels, but the evidence now available seems to favor lateral gradation in deposition as explanation of the irregularities of the sand distribution in the McLouth field.

The porosity and, therefore, the productivity of the McLouth sand is erratic. In some areas, as in the SW NW and NW SW sec. 3, the McLouth sand consists mainly of pervious sandstone, but some wells in and adjacent to the NW SW sec. 4, encountered shale containing only streaks of impervious sand. In the Stark No. 1 Ragan well in NW NE sec. 4, as already pointed out, the McLouth consists almost entirely of shale that bears only thin streaks of impervious sand; this is almost surrounded by wells that encountered enough porous sand to constitute wells of average production. Gas production is dependent on the permeability of the 40 to 50 feet of sandstone and sandy, silty, and micaceous shale that constitute the

McLouth sand. Gas is produced from all parts of the sand that are
sufficiently pervious. Wells that failed to produce gas or oil were
dry because they encountered the McLouth sand at points where
it lacks porosity. The oil wells, Longwell et al. Nos. 1 and 2 Bank-
ers Life (SW sec. 3, T. 10 S., R. 20 E.), and Apperson and Pundt
No. 1 Steenstry (SW SE NW sec. 3, T. 10 S., R. 20 E.) produce oil
from a porous phase of the McLouth sand on the south flank of the
anticline.

The Bankers Life No. 1 well on the south slope of the anticline
penetrated the top of the McLouth sand at an altitude of -342 feet,
27 feet lower than in Longwell et al. No. 2 Steenstry. The latter
well, which is the largest gas producer in the field, is located one
quarter mile north of the Banker's Life No. 1 well. On the north
side of the anticline the Archie et al. No. 1 Shrader well (SE SW
sec. 28, T. 9 S., R. 20 E.) found a considerable amount of oil in the
McLouth sand, which was topped at an altitude of -371, 29 feet
lower than in the McLaughlin No. 1 Bartlett well (lowest gas well
to the south). Judging from these regional relations, it might be
supposed that the gas-oil contact is 30 feet or more lower on the
north side of the anticline than on the south side but other wells
fail to corroborate any regularity of the gas oil contact.

The Anderson No. 1 McLeod-Wisdom well, the second largest
gas well in the field (August 15, 1941), encountered the top of the
McLouth sand in a lower position than in the Archie No. 1 Shrader
well (pl. 3C). Also, the Longwell No. 2 Bartlett well in SW SE sec.
33, T. 9 S., R. 20 E. (on August 15, 1941, not yet drilled in), en-
countered oil in the top of the McLouth sand 36 feet higher than in
the Archie No. 1 Shrader and 7 feet higher than in McLaughlin
No. 1 Bartlett, the latter a gas well. It is probable, therefore, that
the occurrence of oil in the McLouth sand is erratic, and its distri-
bution is in part controlled by factors other than gravitation. No
water has yet been found in the McLouth sand, and the gas ex-
tends far beyond the area of closed contours on the McLouth sand.

TOP OF MISSISSIPPIAN ROCKS

The second producing zone in the McLouth field consists of the
weathered upper part of the Salem (called Spergen by the U.S.
Geological Survey) dolomite, at the top of the Mississippian sec-
tion in this part of Kansas. The zone yields some gas or shows of
oil in all the wells drilled into it. The Young No. 1 McLeod well,

which penetrated the top of the Mississippian on the down-throw side of the fault, had a show of heavy, free oil, but no oil was actually produced. The zone of weathered Mississippian rocks yields gas in McLaughlin No. 2 Bartlett, McLaughlin No. 1 Ragan, Mc-Laughlin No. 2 Dark, and in other wells. The Salem consists of dense, finely sucrose, silty dolomite containing a small amount of chert. Its porosity is due to its position at the top of the local succession of Mississippian rocks and its exposure to weathering and leaching before becoming buried beneath early Pennsylvanian sediments. In many wells the Salem beds are immediately overlain by a sandstone phase of the McLouth sand, but in others (pl. 2) black micaceous and silty shale intervenes.

There is but little chert in the Salem dolomite. The Pennsylvanian basal conglomerate that in most places is composed mainly of residual chert derived from the weathering of uppermost Mississippian rocks is accordingly thin, inconspicuous, or absent in the McLouth area.

BURLINGTON-KEOKUK ZONE

The third producing zone in the McLouth field is a porous cherty dolomite, 10 to 20 feet thick, beneath a thick section of cherty limestone in the undifferentiated Burlington-Keokuk limestone of early Mississippian age. The top of this porous dolomite zone lies 121 to 128 feet below the easily recognizable lower boundary of the Salem (Spergen) rocks. The porous dolomite is the producing zone of the three McLeod oil wells in sections 4 and 5, T. 10 S., R. 20 E. In the discovery well (McLaughlin No. 1 fee, NE NW sec. 4) the Burlington-Keokuk zone is heavily oil-stained at a depth of 1,624 feet, but was not tested because of mechanical difficulties. Water was reported at a depth of 1,635 feet.

The Stark No. 1 Ragan well (NW NE sec. 4), which is 17 feet lower on the Big Springs datum bed, found water in the Burlington-Keokuk zone. The structural relations of this zone indicated by the six wells drilled into it are shown by contours in plate 3F.

### THICKNESS OF PRE-PENNSYLVANIAN STRATIGRAPHIC DIVISIONS

In the McLaughlin No. 1 fee well, the thickness of the Mississippian limestone section is 345 feet, and of the Chattanooga shale 54 feet. In McLaughlin No. 1 Thorpe, sec. 27, T. 10 S., R. 20 E., 4 miles distant, the Devonian limestone (known locally as the "Hun-

ton") rests upon Kimmswick (Viola of oil geologists) limestone. The Maquoketa (Sylvan of Oklahoma) shale, which normally intervenes between the "Hunton" and Kimmswick limestones, was eroded in the vicinity of McLouth and toward the southeast, during a pre-Devonian cycle of erosion. The thickness of the combined Devonian and Kimmswick beds in this well is 394 feet, and that of the St. Peter sandstone is 76 feet.

Approximate depths below the top of the Mississippian rocks of various key horizons, listed in downward order, are as follows: (1) top of Chattanooga shale, 350 feet; (2) top of Devonian ("Hunton") limestone, 400 feet; (3) top of St. Peter sandstone, 800 feet; (4) top of Arbuckle dolomite, 880 feet; (5) top of Roubidoux sandstone, 925 feet; (6) top of pre-Cambrian granite, 1,525 feet. The thickness of the Mississippian strata varies somewhat from well to well, part of this variation being due to erosion of the Mississippian rocks. As may be seen in the cross-sections (pl. 2), the thickness of the upper part, the Salem (Spergen) dolomite, varies according to the structure of the pre-Pennsylvanian rocks and according to the topographic relief of the surface on which the Pennsylvanian rocks were deposited. The amount of erosion which occurred between the deposition of the Devonian rocks and the Kimmswick limestone also varies.

DESCRIPTION OF STRUCTURE CONTOUR MAPS

Plate 3 shows the structure of the rocks in the McLouth field as represented by selected datum horizons, which in downward order are as follows: top of the Oread limestone (pl. 3A), base of the Hertha limestone (pl. 3B), top of the McLouth sand (pl. 3C), top of the Mississippian rocks (pl. 3D), top of the Warsaw limestone (pl. 3E), and top of the porous dolomite in the Burlington-Keokuk limestones (pl. 3F). Control points are those that can be determined from the 36 wells drilled (or drilling) prior to August 15, 1941. The information given in table 2 is based primarily on drillers' logs, checked and corrected by study of well cuttings on file at the State Geological Survey at Lawrence. In a number of the earlier wells the importance of determining depths accurately was not realized and corrections of 10 to 15 feet in the depths to the recorded beds were made in some wells. Two kinds of corrections have been applied. Obvious inaccuracies in some logs are shown by evidence from study of the samples, which indicates that the
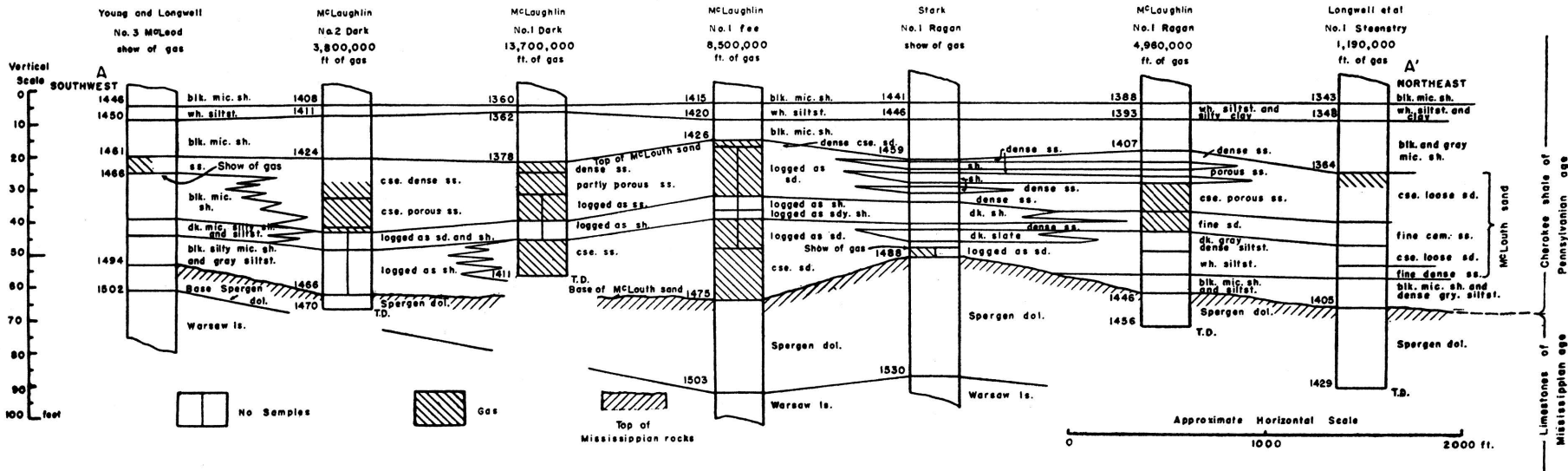
A. Cross-section of McLouth sand along line A-A' (pl. 1) in a northeast direction along crest of McLouth anticline (secs. 3, 4, and 5, T. 10 S., R. 20 E.) Variations in thickness and lithologic character of sand interpreted from study of logs and examination of well cuttings.

Well logs are correlated utilizing the white siltstone horizon, 11 to 21 feet above top of McLouth sand zone, as the upper datum plane.

Some well logs do not record sand unless it contains oil, gas, or water. The top of the gas pay portion of the McLouth sand is below the top of the McLouth sand proper in some wells.

The cross-section also shows the position of the top of the Mississippian rocks and the top of the Warsaw limestone in relation to the white siltstone. On the assumption that the top of the white siltstone was originally horizontal, the top of the Mississippian had a relief of 10 to 12 feet on the line of the cross-section. Depths below surface shown by figures at left of well columns.
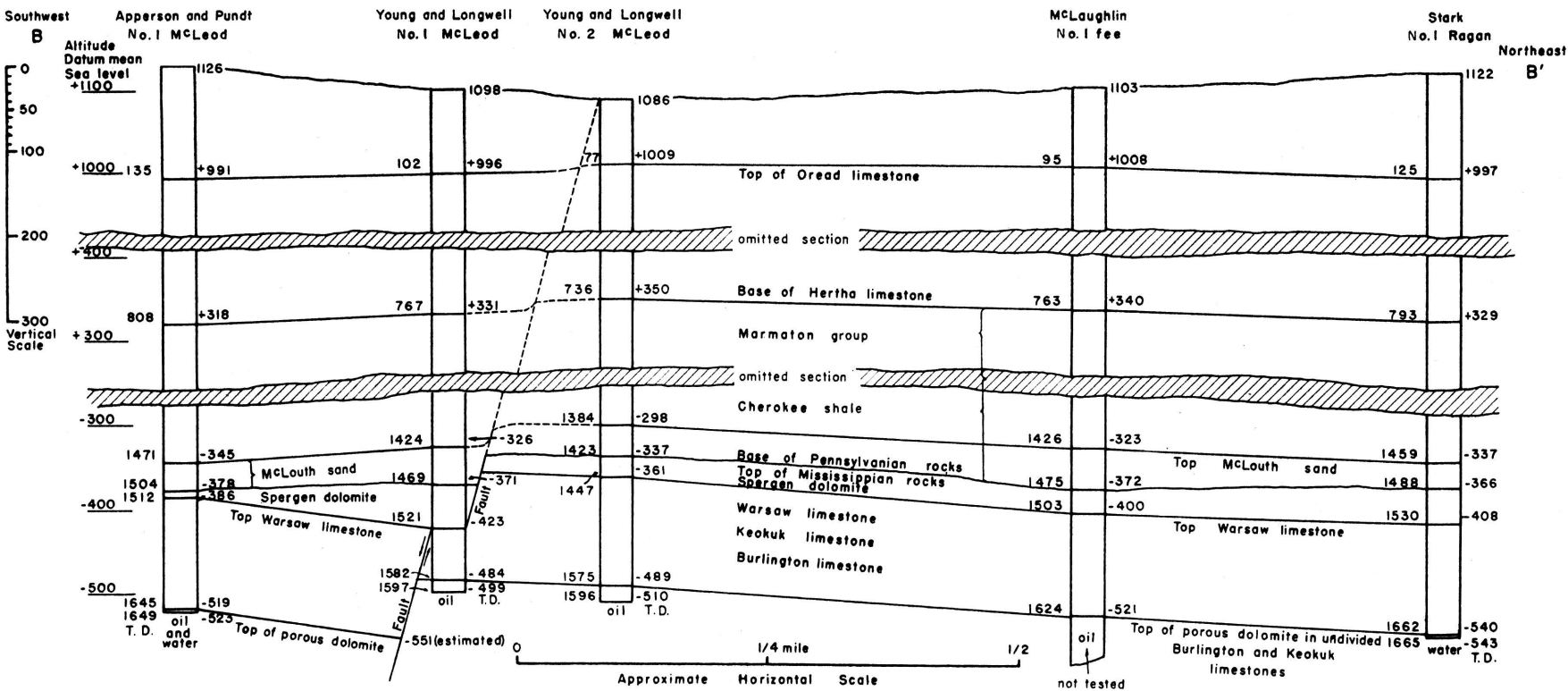
B. Cross-section of McLouth field along line B-B' (pl. 1) showing structural relationships of Pennsylvanian and Mississippian rocks. It is significant that the anticlinal dips are gentle in younger Pennsylvanian rocks but progressively steeper with increasing depth. In older Pennsylvanian rocks the anticlinal crest passes near the Young and Longwell No. 2 McLeod well. In Mississippian rocks the structural crest adjoins a fault, and the crest of the anticline passes near the Young and Longwell No. 1 McLeod well.

The numbers at right of well columns indicate altitude in feet above and below sea-level; those at left indicate depth below land surface. The two cross-ruled bands represent parts of the logs that are omitted in the diagrammatic section.

ABBREVIATIONS

cse—coarse	blk—black	sd—sand
mic—micaceous	siltst—siltstone	sh—shale
wh—white	ss—sandstone	dol—dolomite
ls—limestone	dense—close-grained and lacking in	
cem—cemented	porosity	

exact tops of datum beds are not recorded correctly in the logs. Correction of depths has been made when remeasurement of the hole indicated that the depth, as first recorded, was in error. It is impossible to ascertain whether such an error is the result of accumulated small errors or whether it is the result of mistake in the depth at a single point such as may occur when crews are changed. Corrections of the types just indicated result in departure from depths as given in the logs. Depths as recorded in drillers' logs, as well as corrected depths, are indicated in table 6. Adjustments of this nature are not entirely satisfactory but it is believed that the revised depths are more accurate than those given in the drillers' logs. Discrepancies in contouring the McLouth sand may be introduced by differences of opinion as to what constitutes the top of the McLouth sand, inasmuch as the porosity and general character of strata in the position of the McLouth sand vary from well to well. The top of a coarse sandstone (microscopically determined) that occurs below white siltstone has been used for purposes of structure contouring, although in many wells the top of this coarse sandstone is not the top of the productive zone. Under these circumstances it is probable that no two geologists would produce exactly the same structure maps.

The series of structure maps (pl. 3) shows that the structural relief gradually increases with depth. A rough measure of the increased relief downward is given by the progressively greater depth of each datum in Young and Longwell No. 1 McLeod well below its position in Young and Longwell No. 2 McLeod, as shown in table 3.

TABLE 3. *Differences in altitude of datum beds in Young and Longwell No. 1 McLeod with respect to their position in the Young and Longwell No. 2 McLeod well.*

	feet
Big Springs limestone member of Lecompton limestone (surface)	— 6
Top of Oread limestone	—13
Base of Hertha limestone	—19
Top of McLouth sand	—28
Top of Mississippian limestone	—34
Top of Warsaw limestone, south of fault	—62
Top of porous dolomite (calculated), south of fault	—67
Top of Warsaw limestone (calculated), north of fault	+ 5
Top of porous dolomite, north of fault	+ 5

CHANGES OF STRUCTURE WITH DEPTH

The form of the McLouth anticline, as expressed by the top of the Oread and the base of the Hertha limestones, does not differ greatly from that expressed by the Big Springs limestone at and near the surface, as shown in plate 1. The dip and closure, however, increase with increasing depth, and a southward shift in the position of the crest of the anticline occurs. The structure as expressed by the top of the McLouth sand shows an accentuation of the anticline as compared with that indicated by the Hertha datum. The abrupt southward drop of the top of the sand in SW sec. 3 and SE sec. 4, T. 10 S., R. 20 E., is interpreted as indicating renewed movement of the pre-Pennsylvanian fault in this area during the deposition of the McLouth sand and shortly afterward. Only slight movements over the fault occurred during Pennsylvanian time in SE sec. 4 and SE sec. 5, however.

The resemblance of the fold at the top of the McLouth sand to that at the top of the Mississippian rocks is obvious. These two key horizons are only 45 feet apart. The differences between the contours on the McLouth sand and those on the top of the Mississippian rocks are due mainly to the topographic relief of the surface of the Mississippian; as suggested by the cross-section (pl. 2B), they amount to 10 or 12 feet within the area of the McLouth field.

The structure, as indicated by a datum in the Mississippian rocks, differs from that shown by a Pennsylvanian key horizon. In the surface beds the crest of the anticline is broad. According to Haworth's corrected map (pl. 1), the crest is nearly flat. The Big Springs limestone is higher by only one foot (see pl. 1 and cross-

PLATE 3. Maps showing structure of the McLouth field as expressed by various key horizons: (A) top of Oread limestone, (B) base of Hertha limestone, (C) top of McLouth sand, (D) top of Mississippian limestone, (E) top of Warsaw limestone, and (F) top of porous dolomite in undifferentiated Burlington–Keokuk limestone 128 feet below top of Warsaw. The maps show increasing steepness of dips with increasing depth and they indicate a southward shift of the anticlinal crest from the position defined by the structure of surface beds (Big Springs limestone) near McLaughlin No. 1 fee in NE NW sec. 4 (fig. 2) to a position on the upthrow side of the fault in Mississippian rocks in Young and Longwell No. 1, McLeod in NW SW sec. 4 (pl. 3F).

Contour interval, 10 feet. Figures below well symbols represent altitudes at which contoured horizons were encountered in wells. Wells for which complete information had not been obtained or which had not been completed by August 15, 1941 are marked (a).

Initial production of oil and gas by wells in McLouth sand is shown in plate 3C. Initial production of oil from wells in Mississippian dolomite is shown in plate 3F.

A

Structure contours
on top of
Oread limestone

Jefferson Co.
Leavenworth Co.

R 20 E

T 9 S

T 10 S

B

Structure contours
on base of
Hertha limestone

Jefferson Co.
Leavenworth Co.

R 20 E

T 9 S

T 10 S

C

Structure contours
on top of
McLouth sand

Jefferson Co.
Leavenworth Co.

Probable Fault

Initial open flow of gas wells in
millions of cubic feet per day is shown
above wells.   Initial production of oil
wells in barrels per day is shown at right.

R 20 E

T 9 S

T 10 S

D

Structure contours
on top of
Mississippian limestones

Jefferson Co.
Leavenworth Co.

Fault

R 20 E

T 9 S

T 10 S

E

Structure contours
on top of
Warsaw limestone

Jefferson Co.
Leavenworth Co.

Fault

R 20 E

T 9 S

T 10 S

F

Structure contours
on top of
Burlington and Keokuk
porous dolomite zone

Jefferson Co.
Leavenworth Co.

Fault

Initial production of oil in barrels
per day is shown at right of wells.

R 20 E

T 9 S

T 10 S

section, pl. 2B) in the discovery well than it is in Young-Longwell No. 2 McLeod well. On the top of the Oread, the crest differs but slightly from that on the Big Springs limestone. The differences shown by the altitudes of the crests of these beds is probably less than the error in determining the altitudes. On the base of the Hertha limestone and on the top of the McLouth sand, however, the crest of the anticline is definitely in Young and Longwell No. 2 McLeod; and, as has already been pointed out, the deformation here has increased considerably.

In the Mississippian rocks two datum beds have been used; one of these is the top of the Warsaw limestone, the other is the top of a porous dolomite in the undifferentiated Burlington-Keokuk limestone, 128 feet lower. On the north side of the fault (pl. 2B), both of these datum horizons rise regularly from Stark No. 1 Ragan to Young No. 1 McLeod well, where the Mississippian rocks at their highest known point abut against the fault. Immediately south of the fault they are estimated to be at least 62 feet lower structurally, but in Apperson No. 1 McLeod these beds apparently rise again toward the south (pl. 2B).

A fault displacement of 62 feet is expressed in the Warsaw limestone. The top of the McLouth sand in the Young-Longwell No. 1 McLeod well, however, is only 28 feet lower than it is in No. 2 McLeod, indicating that about 34 feet of the displacement of Mississippian rocks had occurred prior to the deposition of the Pennsylvanian beds. The base of the Hertha and the top of the Oread limestones show, respectively, 19 and 13 feet difference in altitude in the two wells. Only 6 feet difference in altitude was noted by Haworth in the surface rocks. These relations indicate existence of a pre-Pennsylvanian fault having a throw of about 34 feet. Faulting of the Mississippian rocks was increased from 34 to 62 feet during Pennsylvanian deposition. The displacement in the Pennsylvanian rocks, which consist chiefly of shale, seems to be expressed mainly by a steepening of their dip. The deformation of the early Pennsylvanian strata was increased by slight movements during the deposition of the later Pennsylvanian rocks. The uppermost Pennsylvanian rocks were deposited after most of the movement had taken place, so that the deformation dies out as the surface is approached. The surface beds show little or no expression of the fault and even their dip is low.

It is important to note that the crest of the anticline in the Miss-

TABLE 4. *Analysis of crude oil from McLouth sand in Longwell et al. No. 1 Bankers' Life (Fred McLeod), NW SW sec. 3, T. 10 S., R. 20 E., McLouth oil and gas field, Leavenworth county, Kansas. Depth 1,438 to 1,450 feet.*

GENERAL CHARACTERISTICS

Specific Gravity .... 0.905   A.P.I. Gravity 24.9
Per cent Sulphur .... 0.75   Pour point .... 5°F
Saybolt Universal Viscosity at 100°F. 424 sec.   Color .... Black

DISTILLATION, BUREAU OF MINES, HEMPEL METHOD

(1) Dry Distillation; Barometer, 634 mm; First Drop, 86° C (187° F)

Temperature °C	Per cent cut	Sum per cent	Sp. Gr. of cut	A.P.I. of cut	Viscosity at 100° F.	Cloud test °F.	Temperature °F.
Up to 50	....	....	....	....	....	....	Up to 122
50- 75	....	....	....	....	....	....	122–167
75–100	0.8	0.8					167–212
100–125	2.1	2.9	.747	57.9			212–257
125–150	2.5	5.4					257–302
150–175	3.3	8.7	.754	56.2	....	....	302–347
175–200	4.5	13.2	.763	54.0	....	....	347–392
200–225	5.1	18.3	.774	51.3	....	....	392–437
225–250	5.8	24.1	.786	48.5	....	....	437–482
250–275	9.1	33.2	.802	44.9	....	....	482–527

(2) Vacuum distillation at 40 mm.

Temperature °C	Per cent cut	Sum per cent	Sp. Gr. of cut	A.P.I. of cut	Viscosity at 100° F.	Cloud test °F.	Temperature °F.
Up to 200	0.1	0.1					Up to 392
200–225	4.7	4.8	.843	36.4	45	30	392–437
225–250	4.1	8.9	.858	33.4	52	45	437–482
250–275	3.8	12.7	.877	29.9	69	60	482–527
275–300	6.2	18.9	.895	26.6	115	75	527–572

Carbon residue of residuum, 20.2 percent; Carbon residue of crude, 10.3 percent.

APPROXIMATE SUMMARY

	Per cent	Sp. Gr.	°A.P.I.	Viscosity
Light gasoline	0.8	....	......:	
Total gasoline and naptha	13.2	.754	56.2	
Kerosene distillate	20.0	.790	47.6	
Gas oil	5.6	.844	36.2	Below 50
Nonviscous lubricating distillate	8.6	.854–.889	34.2–27.7	50–100
Medium lubricating distillate	4.7	.889–.906	27.7–24.7	100–200
Viscous lubricating distillate	....	....	....	....
Residuum	46.0	1.019	....	....
Distillation loss	1.9	....	....	....

Base, Paraffin—intermediate

TABLE 5. *Analysis of crude oil from Mississippian dolomite in Young and Longwell No. 3 (Bessie McLeod), NE SE sec. 5, T. 10 S., R. 20 E., McLouth oil and gas pool, Jefferson county, Kansas. Depth 1,635 to 1,644 feet.*

GENERAL CHARACTERISTICS

Specific Gravity .... .912   A.P.I. gravity 23.7
Per cent Sulphur .... 0.77   Pour point .... 5° F.
Saybolt Universal Viscosity at 100° F. 695 sec.   Color .... Black

DISTILLATION, BUREAU OF MINES, HEMPEL METHOD

(1) Dry Distillation; Barometer, 635 mm; First Drop, 83°C (181°F)

Temperature °C	Per cent cut	Sum per cent	Sp. Gr. of cut	°A.P.I. of cut	Viscosity at 100°F.	Cloud test °F.	Temperature °F.
Up to 50	....	....	....	....	....	....	Up to 122
50- 75	....	....	....	....	....	....	122-167
75-100	0.7	0.7			....	....	167-212
100-125	1.6	2.3	.741	59.5	....	....	212-257
125-150	2.3	4.6			....	....	257-302
150-175	3.3	7.9	.756	55.7	....	....	302-347
175-200	4.3	12.2	.764	53.7	....	....	347-392
200-225	4.9	17.1	.775	51.1	....	....	392-437
225-250	5.9	23.0	.788	48.1	....	....	437-482
250-275	9.8	32.8	.802	44.9	....	....	482-527

(2) Vacuum distillation at 40 mm.

Temperature °C	Per cent cut	Sum per cent	Sp. Gr. of cut	°A.P.I. of cut	Viscosity at 100°F.	Cloud test °F.	Temperature °F.
Up to 200	0.4	0.4			....	....	Up to 392
200-225	5.2	5.6	.847	35.6	46	30	392-437
225-250	3.7	9.3	.863	32.5	55	45	437-482
250-275	3.8	13.1	.882	28.9	78	60	482-527
275-300	11.7	24.8	.897	26.3	136	75	527-572

Carbon residue of residuum, 21.3 per percent; Carbon residue of crude, 9.8 percent.

APPROXIMATE SUMMARY

	Per cent	Sp. Gr.	°A.P.I.	Viscosity
Light gasoline	0.7	....	....	....
Total gasoline and naphtha	12.2	.753	56.4	....
Kerosene distillate	20.6	.792	47.2	....
Gas oil	4.9	.846	35.8	Below 50
Nonviscous lubricating distillate	9.2	.854-.888	34.2-27.9	50-100
Medium lubricating distillate	10.7	.888-.908	27.9-24.3	100-200
Viscous lubricating distillate	....	....	....	....
Residuum	41.8	1.022	....	....
Distillation loss	0.6	....	....	....
Base, Paraffin-intermediate				

issippian rocks adjoins the fault (pl. 2B) in the Young and Long-
well No. 1 McLeod well. The crest of the anticline in the Pennsyl-
vanian rocks is ill-defined and low. The cross-section (pl. 2) in-
dicates that the crest of the surface rocks passes through the lo-
cation of the McLaughlin No. 1 fee well, or near to it. The crest of
the anticline shifts materially with increasing depth, although per-
haps not as much as the half mile that separates the McLaughlin
and McLeod wells, since this distance is measured diagonal to the
strike of the fold. The surface beds between these two wells drop 7
feet toward the southwest, but the top of the porous dolomite zone
of the Burlington-Keokuk beds rises 37 feet in the same direction.

The first structure map of the surface beds prepared by Ha-
worth from outcrops and shallow pits is presented in fig. 2 for
comparison with the map as later revised by the addition of data
furnished by wells. The slight saddle that was later indicated on
the crest of the anticline was not evident from study of the out-
crops. According to the structure as represented on Haworth's
original map, the site of the Stark No. 1 Ragan well seems almost, if
not quite, as favorably located for a test as the site of McLaughlin
No. 1 fee well which was finally chosen. The Stark No. 1 Ragan
well, however, is one of the few unproductive wells in the pool
(August 15, 1941). It encountered the McLouth sand at a point
where there is no appreciable porosity and it found water in the
porous Mississippian dolomite (Burlington-Keokuk), which was
penetrated 57 feet down dip from its position in the No. 1 McLeod
where oil was present.

It is almost certain that if the first well drilled in the McLouth
area had been Stark No. 1 Ragan, the anticline would have been
abandoned, as in the case of other low anticlines of the Forest City
basin that have been tested and found dry. The fact that the crest
of the anticline shifts laterally in the deeper rocks would not have
been indicated by the single well nor would the presence of porous
and productive gas sands at a point only one location distant have
been discovered. It is not impossible, therefore, that some anti-
clines in the Forest City basin that have been considered ade-
quately tested have been unnecessarily condemned, through fail-
ure to recognize the relation of the structure in the Pennsylvanian
to folds and faults in pre-Pennsylvanian rocks. The differences,
both in the amount and in the position of maximum deformation at
various depths, indicate that the "amoebic" structure of the sur-

Wells	Loc. ¼¼	Sec.	Twp. S	Rge. E	Location (footage)	Init. oil Miss. sand	Init. oil McLouth sand	Init. gas McLouth sand	Alt. mouth	Oread depth	Oread depth (corr.)	Alt. top Oread	Hertha base depth	Hertha base depth (corr.)	Alt. base Hertha	McLouth depth	McLouth depth (corr.)	Alt. top McLouth	Miss. depth	Miss. depth (corr.)	Alt. top Miss.	Warsaw depth	Warsaw depth (corr.)	Alt. top Warsaw	Burl.-Keokuk depth	Alt. top Burl.-Keokuk	Total depth
Archie et al. No. 1 Shrader	SE SW	28	9	20	610 ft. from E. line 660 ft. from S. line		show	0.396	1071	110	112	959	765	767	304	1442		-371	1468		-397						1472
Anderson No. 1 McLeod-Wisdom	SW NW	29	9	20			0	15.250	1053	102		951	759		294	1436	1434	-381									1455
Jackson No. 1 Shrader	NW NE	32	9	20			(a)	(a)	1088	155	156	932	830		258	1472		-384	1520		-432						(a)
Archie et al. No. 1 Brose	NE SE	32	9	20			trace	1.070	1084	125	122	962	798		286	1450	1460	-376	1515		-431	1530		-446			1575
Magnolia No. 1 Harris	SW SE	32	9	20			0	12.250	1096	120	115	981	770		326	1430		-334									1450
Magnolia No. 1 Davison	SE SE	32	9	20	660 ft. from S. line 560 ft. from E. line		0	10.500	1067	85		982	752	747	320	1399	1388	-321									1411
Anderson et al. No. 1 Woodhead	NE SW	32	9	20	515 ft. from N. line 680 ft. from E. line		0	13.000	1131	168		963	820	828	303	1487		-356									1505
McLaughlin & Sons Co. No. 1 Bartlett	SW SW	33	9	20	757 ft. from W. line 677 ft. from S. line		0	7.000	1052	73		979	739		313	1398	1394	-342									1424
McLaughlin & Sons Co. No. 2 Bartlett	SE SW	33	9	20	739 ft. from S. line 789 ft. from E. line		0	6.100	1099	110		989	775		324	1433	1431	-332	1473		-374						1485
McLaughlin & Sons Co. No. 3 Bartlett	NW SW	33	9	20			(a)	(a)	1042	90	80	962	751	757	285	1403		-361									(a)
Longwell et al. No. 1 Bartlett	NW SE	33	9	20		(a)	(a)	5.458	1107	105		1002	755	772	335	1430	1425	-318									1462
Longwell et al. No. 2 Bartlett	SW SE	33	9	20		(a)	(a)		1099	95		1004	768		331	1429	1434	-335	1463		-364						(a)
A & B Pipeline Co. No. 1 Edmonds	SW SW	34	9	20		(a)	0	2.700	1066	60	68	998	711	738	328	1393	1392	-326	1447	1433	-367	1444		-378			1447
Apperson and Pundt No. 1 Steenstry	SE NW	3	10	20			(a)	(a)	1071	80	70	1001	740	746	325	1428		-357									1473
McLaughlin & Sons Co. No. 1 Ragan	NW NW	3	10	20	631 ft. from W. line 495 ft. from N. line		0	4.960	1092	85		1007	758		334	1412	1407	-315	1446		-354						1456
Longwell et al. No. 1 Steenstry	NE NW	3	10	20	609 ft. from N. line 795 ft. from E. line		0	1.190	1044	45	38	1006	700	710	334	1364		-320	1405		-361						1429
Longwell et al. No. 2 Steenstry	SW NW	3	10	20	660 ft. from N. line 581 ft. from E. line		0	16.840	1058	50		1008	715	728	330	1375	1373	-315									1393
Longwell et al. No. 1 Bankers Life (McLeod)	NW SW	3	10	20	660 ft. from W. line 581 ft. from N. line		55	0	1096	100		996	757	763	333	1439	1438	-342									1475
Longwell et al. No. 2 Bankers Life (McLeod)	NE SW	3	10	20	585 ft. from N. line 600 ft. from E. line		65	0	1042	50		992	710	715	327	1375		-333									1420
Stark et al. No. 1 Ragan	NW NE	4	10	20	415 ft. from N. line 710 ft. from W. line	0		0	1122	125		997	793		329	1459		-337	1488		-366	1533	1530	-408	1662	-540	1665
A & B Pipeline Co. No. 1 Ragan	SE NE	4	10	20	660 ft. from S. line 660 ft. from E. line		0	6.070	1103	105		998	780		323	1420		-317									1440
McLaughlin & Sons Co. No. 1 fee	NE NW	4	10	20	1110 ft. from N. line 920 ft. from E. line	●	0	8.500	1103	104	95	1008	770	763	340	1426		-323	1475		-372						1915
McLaughlin & Sons Co. No. 2 fee	NW NW	4	10	20	660 ft. from W. line 100 ft. from E. line		0	4.000	1087	90	88	999	752	758	329	1412	1410	-323									1457
Stark et al. No. 1 McLaughlin	NW NW	4	10	20	263 ft. from W. line 572 ft. from N. line		0	10.200	1082	89		993	748	746	336	1413	1410	-328									1442
McLaughlin & Sons No. 1 Dark (McLaughlin)	SW NW	4	10	20	1150 ft. from S. line 451 ft. from W. line		0	13.700	1074	69		1005	736	742	332	1379	1378	-304									1411
Young and Longwell et al. No. 1 McLeod	NW SW	4	10	20	835 ft. from N. line 600 ft. from W. line		25	0	1098	108	102	996	762	767	331	1424		-326	1469		-371	1521		-423	1582	-484	1597
Young and Longwell et al. No. 2 McLeod	NW SW	4	10	20	430 ft. from W. line 150 ft. from N. line		(a)	0	1086	72	77	1009	736		350	1389	1384	-298	1423		-337	1454	1447	-361	1575	-489	1596
Magnolia No. 1 Kell estate	NE SE	4	10	20		0	trace	0	1094	105		999	785		309	1451	1450	-356	1539		-445	1568		-474			1645
Sherrod et al. No. 1 Momyer	NW SE	4	10	20		0	trace	0	1144	155		989	845		299	1498		-354	1573		-429	1612		-468			1682(a)
A & B Pipeline Co. No. 1 McLeod	SE NW	4	10	20	330 ft. from W. line 71 ft. from S. line		(a)	(a)	1139	135		1004	800	810	329	1491	1474	-335	1510	1504	-365						(a)
A & B Pipeline Co. No. 1 Bower	NE NE	5	10	20	572 ft. from N. line 622 ft. from E. line		0	6.018	1117	115	126	997	790		327	1440	1442	-325	1466		-352						1473
McLaughlin & Sons Co. No. 2 Dark (Bower)	SE NE	5	10	20	675 ft. from S. line 560 ft. from E. line		0	3.800	1114	111		1003	780	783	331	1431	1424	-310									1470
Sherrod et al. No. 1 Bower	SW NE	5	10	20	863 ft. from W. line 777 ft. from S. line		0	7.400	1157	160		997	827		330	1482		-325									1501
Young and Longwell et al. No. 3 McLeod	NE SE	5	10	20	585 ft. from N. line 610 ft. from E. line		90	0	1147	149	141	1006	812	815	332	1461	1474	-327	1494	1507	-360	1502	1515	-368	1636	-488	1644
Apperson and Pundt No. 1 McLeod	SE SE	5	10	20	330 ft. from N. line 330 ft. from E. line		0	0.325	1126	135		991	803	808	318	1471		-345	1497	1504	-378	1512		-386	1645	-519	1649
Richard No. 1 Sherman	NE NE	6	10	20			0	13.240	1136	155	170	966	840		296	1508	1504	-368									1518

TABLE 6. *Records of wells in the McLouth field drilled prior to August 15, 1941, giving surface elevation, production, depths below the surface and altitudes of key horizons as derived from well logs, and as corrected for use in structure maps and cross-sections.*

Locations and elevations of wells reported by Huntsman Haworth, supplemented by plane-table studies and direct measurements by L. L. Armstrong, A & B Pipeline Company. Names of original fee owners are used in naming wells; names of subsequent purchasers are given in parentheses. Oil production in barrels per day and gas production in million cubic feet per day.

Wells for which complete information had not been obtained or which had not been completed by August 15, 1941 are marked (a).

face formations is the faint expression of more definite and stronger folding and faulting in the older rocks. The interpretation of the meaning of the surface structural features in terms of the deeper rocks will depend on a better understanding of the nature—still only slightly known—of the pre-Pennsylvanian deformation of eastern Kansas.

ANALYSES OF OIL

The preceding analyses of oil from the McLouth pool were made by J. G. Crawford in the laboratory of the Federal Geological Survey at Casper, Wyoming, under the direction of H. J. Duncan, Supervisor. The first (table 4) is an analysis of oil from the McLouth sand taken from the Longwell et al. No. 1 Bankers Life well. The second (table 5) is an analysis of oil from Mississippian dolomite 128 feet below the top of the Warsaw and 141 feet below the top of the Mississippian in Young and Longwell No. 3 McLeod.

RELATION OF GAS AND OIL TO STRUCTURE

During the latter part of July and the early part of August, 1941, the gas-producing area of the McLouth field was extended 1¼ miles to the northwest by Anderson No. 1 McLeod-Wisdom in SW NW sec. 29, T. 9 S., R. 20 E. The open flow of this well gauged 15,-250,000 cubic feet per day. Richard No. 1 Sherman in NE NE sec. 6, T. 10 S., R. 20 E., which gauged 13,240,000 cubic feet per day, extended the producing area ¾ mile to the west. These two wells penetrated the McLouth sand respectively 83 and 70 feet below the highest point on the McLouth anticline (pl. 3C). These and other wells have extended the gas-producing area far beyond the area of closed contours of the McLouth anticline as mapped on the McLouth sand. This fact and the absence of water saturating the McLouth sand in wells drilled to August 15, 1941, suggest that structure is less important than porosity in controlling the distribution of gas in the McLouth sand, or, alternatively, that the McLouth anticline is only a part of a much larger structural trap. There can be no doubt that the distribution of oil in the Mississippian rocks, however, is controlled by the structural attitude of the reservoir rocks. The presence of oil in the porous zone of the Mississippian at the structural crest and the presence of water in the same zone on the flank of the fold indicate definitely the importance of structure in controlling the distribution of the oil in the Mississippian rocks and probably also in older rocks not yet tested.

The deeper zones below the Mississippian should be tested along the structural crests and not necessarily below large gas wells in the McLouth sand or where a flank well found the McLouth sand unproductive.

The data on the McLouth field are as yet insufficient as a basis for satisfactory conclusions as to controlling factors in the occurrence of the oil and gas. One may formulate a hypothesis covering these factors, but the ideas expressed below are tentative and subject to revision as more data are secured from future drilling.

A comparison of the analyses of oil from the McLouth sand and oil from the dolomite zone of the Mississippian shows an extraordinary similarity. This strongly suggests that the oil in the lower Pennsylvanian rocks has escaped from the Mississippian limestone into the McLouth sand. The oil in both zones may have been derived from a deeper source. Up to the present the oil in the McLouth sand has been found mainly near the fault and this oil occurs at higher elevations in the sand than the gas obtained from many wells in other parts of the field (pl. 3C). It seems probable that the oil entered the McLouth sand along a shatter zone or along fractures accompanying the fault. Also, there may be more than one fault. It seems probable that gas escaped from Mississippian rocks into the Pennsylvanian sandstone, following the same route as the oil, at first occupying parts of the McLouth sand that are structurally higher than those occupied by the oil. The gas entering the porous and permeable parts of the McLouth sand would tend to expand mushroom-like from the point or points of entrance. Water, if present, would be pushed back down dip until hydrostatic balance between gas pressure and water pressure was reached. As the Pennsylvanian rocks were eroded the hydrostatic head would be reduced and further gradual expansion of the gas into permeable beds would take place. A weakness of this hypothesis lies in the irregularity of the sand and its erratic permeability. It might be supposed that gas advancing into water-saturated beds of varying porosity like the McLouth sand would trap some water in irregularly shaped and partly closed pockets of porous sand. Up to the present time no water-bearing sandstones have been encountered in the McLouth sand zone, although a few of the producing gas wells, when blown, spray some accumulated water of unknown origin.

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